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A Temporal Constraint Theory to Explain Opportunity-Based Spatial Offending Patterns

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This article will examine the evidence supporting the notion that a proportion of offending is driven by the availability of opportunities presented in the routine activities of offenders' lives. It then proceeds to summarize Miller's time measurement theory in order to describe a basic language with which to discuss the movement of people through time and space. Armed with a notation for space–time interactions, the article explores the criminological implications of temporal constraints as a mechanism to explain a number of key concepts from environmental criminology. It is hypothesized here that the temporal constraints of daily life are the main cause of unfamiliarity with areas beyond the offender's immediate least-distance path. As a result, temporal constraints, in conjunction with the locations of offender nodes, are a major determinant in spatio-temporal patterns of property crime.

Keywords: *routine activities; offender behavior; spatial patterns; temporal constraints*

Environmental criminology has been dominated in recent years by a number of key theories that have dictated thinking and research about the spatial behavior of offenders and potential offenders. These concepts place heavy emphasis on the microspatial interactions of an offender and a target, interactions that occur between offender and target in the physical world at a place, defined as a discrete location in time and space (Brantingham and Brantingham 1981). During the same period, it has become commonplace for researchers and practitioners to map a discrete location in space with

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some accuracy (Chainey and Ratcliffe 2005). As a result, the spatial dimension to crime has received much attention in recent years. Though new approaches, such as geographic profiling (Rossmo 2000) have advanced our understanding of offender behavior in a spatial context, there has been far less emphasis on the temporal patterns of offender spatial behavior. Indeed, though time plays a role in many of the key theories related to environmental criminology, little mention of temporality appears in the literature on microspatial criminal behavior.

One of the possible reasons for the emphasis of spatial over the temporal in the recent research may be attributable to the growth of geographic information systems (GIS) and geographic information science (GISc). The recent increase in the ability of researchers to access and analyze spatially referenced crime data has improved the cone of resolution from large national districts (Guerry 1833) to the routine analysis of crime data mappable to the level of the street intersection or individual address (Groff and LaVigne 2001).

Fortunately, new work by geographers concerned with the temporal behavior of people across space provides an opportunity to explore the spatio-temporal dimension to offending with greater clarity. In particular, recent work by Miller (2005) has converted Hägerstrand's (1970) time geography to a formal notation, which will allow crime researchers to better articulate the spatio-temporal behavior of victims and offenders. This article acts as a bridge between a number of relevant crime theories and Miller's measurement theory. It seeks to describe the basic principles of Miller's approach, and then demonstrate how these principles can be applied to offender behavior in order to better understand spatio-temporal patterns of offending. In doing so, the aim is to redress the balance and invigorate the temporal component within environmental criminology.

This article will examine the evidence supporting the notion that a proportion of offending is driven by the availability of opportunities presented in the routine activities of offenders' lives. The emphasis here is on that offending that is opportunistic in nature. It then proceeds to summarize Miller's (2005) time measurement theory in order to describe a basic language with which to discuss the movement of people through time and space. Armed with a notation and a way to articulate space–time interactions, the article explores the criminological implications of temporal constraints as a mechanism to explain a number of key concepts from environmental criminology. The article suggests that the temporal constraints imposed by a need to be at a certain place at a certain time inhibit criminal behavior and the spatial search patterns of many offenders, and this insight has implications for criminal justice policy.

Opportunity and Offender Travel Patterns

Environmental criminology concerns itself with the crime event—the interaction at a place and a time between an offender and a target. Routine activity theory emphasizes this interaction, adding the additional requirement of the interaction taking place in the absence of an inhibiting factor such as a place manager, guardian, or intimate handler (Felson 1995, 1998). These inhibiting features can act as a constraint on criminal opportunity. Routine activity theory has a predominantly victim focus concerning itself with the propensity of criminal victimization and the spatial availability of targets, be they people or property (Cohen and Felson 1979). The completion of a criminal act also requires the offender to make a choice that the rewards will outweigh the perceived risk of capture (Clarke and Felson 1993; Cornish and Clarke 1986).

The rational choice perspective (Clarke and Cornish 1985), an informal decision-based version of rational choice theory (Clarke and Felson 1993:6) recognizes that much offending is opportunity driven (Felson and Clarke 1998) and that the spatial location of an offense is a prime site for crime reduction tactics. Rational choice thinking therefore has a microspatial focus. In other words, the rational choice perspective is less concerned with any general decision to engage in offending but is focused on the specific decision to engage in a crime at the point of commission. The suitability of the opportunity becomes central to the decision-making process, and this is recognized by the rational choice perceptive, which acknowledges the importance of opportunity as a disinhibiting factor.

The situational component of the crime event location has grown in research focus in recent years, with the emergence of spatially enthusiastic research areas such as the geography of crime (Harries 1999), problem-oriented policing (Eck and Spelman 1987; Goldstein 1990; Sherman et al. 1998) and crime prevention through environmental design (Jeffery and Zahm 1993; Taylor 2002). Clarke and Felson note (1993) that all of these approaches, "seem to have accepted a similar image of the criminal in which temptation and opportunity are central to the explanation of crime" (p. 10).

Although opportunity is vital to the commission of many crimes, criminal opportunities are not distributed uniformly across time and space. Many types of offending display significant clustering, with that clustering driven largely by variations in opportunity as well as guardianship patterns. For example, car crime can cluster in poorly protected public car parks (Tilley 1993); residential burglary displays both temporal and spatial clustering, being a predominantly daytime offense (Ratcliffe 2001) with a high occurrence of repeat victimization (Anderson, Chenery, and Pease 1995; Tilley and Webb 1994; Townsley, Homel, and Chaseling 2000); and bars and taverns are magnets for a range of violent offenses late at night (Brantingham and Brantingham 1995). Much of this micro-level clustering can be attributed to features of the urban mosaic acting as crime generators (Brantingham and Brantingham 1995). The existence of crime generators suggests that much offending occurs along the normal, *noncriminal* travel patterns of offenders, as opportunity-driven activity and not a planned and predetermined action. Given the importance of opportunity, the next section explores our understanding of offender access to opportunity.

Crime pattern theory suggests that offender travel patterns are dominated by nodes (Brantingham and Brantingham 1993) that form anchor points (Rengert 1992) in the daily routine of offenders' lives. These nodes can include home, work, school (Rengert and Wasilchick 1985), and also include the home addresses of friends (Wiles and Costello 2000). Some nodes have a strong temporal characteristic. For example, students who are expected to be at school by a certain time and to remain there for a defined amount of time are limited in their spatial range of activity by spatio-temporal constraints on freedom of movement. Similarly, if an offender wishes to remain employed, a work location is a node with a strong spatio-temporal draw, requiring the offender to confine their spatial activity to one site for a substantial part of the work day. Other nodes are more discretionary. Restaurants, bars, and sporting activities are not as compulsory as school or work and have a lesser temporal rigidity in the daily life of an offender. Costello and Wiles report the case of a Sheffield (UK) burglar who had two distinct nodes, home and an area where he bought drugs (Wiles and Costello 2000:40). Although the latter node can be highly discretionary, home can provide a node with varying levels of temporal discretion, depending on the domestic arrangements. In other words, an offender (especially a single adult offender) can come and go as he or she pleases, whereas a single mother with preschool children in the home is more constrained. At the individual level, our understanding of offender decision making and the choices that are made in the face of crime opportunities is heavily influenced by ethnographic work with offenders.

Much of the research into opportunity structures in criminal offending has come from the area of burglary, both residential (Farrell and Pease 1994; Groff and LaVigne 2001; Hakim, Rengert, and Shachmurove 2001; Maguire 1982; Martin 2002; Ratcliffe and McCullagh 1999; Rengert and Wasilchick 2000; Robinson 1999) and nonresidential (Bowers, Hirschfield, and Johnson 1998; Burquest, Farrell, and Pease 1992). A body of ethnographic research confirms the importance of opportunities that become available during the routine activity of burglars' lives:

> Reconstructions of past burglaries revealed that burglars are much more spontaneous and opportunistic than previously reported. The reconstructed burglaries followed three patterns: (a) The burglar happened by the potential burglary site when the occupants were clearly absent and the target was perceived vulnerable (open garage door, windows, etc.); (b) the site had been previously visited by the burglar for a legitimate purpose (as a guest, delivery person, maintenance worker, etc.); or (c) the site was chosen after "cruising" neighborhoods and detecting an overt or subtle cue that signaled vulnerability. (Cromwell, Olson, and Avary 1999:51)

What is noticeable is that only the third target-identification strategy involves a deliberate search for a crime opportunity. The others involved opportunities that were presented as a result of routine travel that was not ostensibly criminal in nature. Cromwell and his colleagues found that opportunity was the predominant characteristic of more than 75 percent of the burglaries they researched (Cromwell et al. 1991:49). This dominance of opportunity over planned activity was also confirmed by Costello and Wiles (2001) during their interviews with 60 burglars in Sheffield. Wright and Decker (1994) found that even when offenders were deliberately searching for a burglary opportunity, it does appear that they either went out to houses that they had identified through earlier noncriminal journeys (p. 63) or searched in areas that they were familiar with (p. 87). Though the offenders who left home to deliberately burgle a predetermined house were in the majority of offenders studied by Wright and Decker, they report that the identification of these homes occurred during more routine activity patterns, and that the burglars interviewed "usually did not go out with the specific intention of looking for potential targets" (Wright and Decker 1994:79). In other words, the potential vulnerability of a target was determined during a trip that was ostensibly noncriminal.

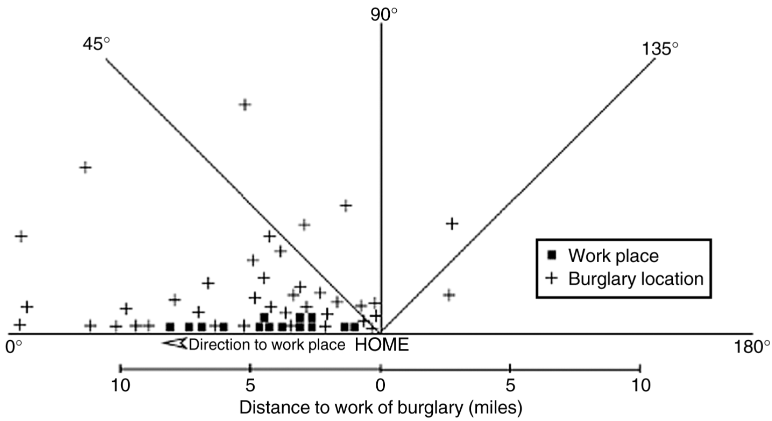
The research of Rengert and Wasilchick (2000) is one of the few to examine explicitly the temporal component of burglary patterns. They reported that the burglars they interviewed were predisposed to offense times of late morning or early afternoon, to coincide with the greatest likelihood of finding a house unoccupied. The offenders who worked at night preferred weekend nights (p. 31). This recognition that the behavior of victims acts as a predictor of criminal activity has its origins in the original paper that introduced routine activity theory (Cohen and Felson 1979) and in the growth of burglary as a daytime activity in the United States from about the 1960s, coinciding with the increase of women in the workforce (Rengert and Wasilchick 2000).

Burglar number 28, as interviewed by Rengert and Wasilchick (2000), is unusual due to the planning that he conducted to commit a burglary. He would begin searching for a suitable residence to target at about 1 p.m., though would spend 30 minutes casing the house and area. He would also then use a small motorcycle that he kept in the trunk of his car and locate it nearby in case an urgent getaway was required. All of this planning took time and he would not return home until 4 p.m. (Rengert and Wasilchick 2000:40). Even though his crime planning was quite complex, he still had to search for possible targets and seek out suitable opportunities when the ‘environmental cues’ (Cromwell, Olson, and Avary 1999:51) suggested a good opportunity.

The substantial journey-to-crime literature (see Costello and Wiles 2001, Rengert 1992, and Rossmo 2000, for a summary of this work) confirms that offenders do not, in general, travel substantial distances to commit offenses, and this is consistent with patterns of crime that are the result of availability of opportunities encountered during noncrime journeys, journeys that are usually as short as possible. Although distances to crime are generally short (Ratcliffe 2003, Rossmo 2000) Costello and Wiles (2000) caution that journey to crime estimates based on the distance from the offender’s home address will overestimate the journey to crime. This is due to the number of offenders who use the home address of a friend as a more common anchor point for criminal journeys. In an innovative approach, Rengert and Wasilchick (2000) incorporated both distance and direction when analyzing their group of 32 burglars. Their graphs use a baseline of the direction from the offenders’ homes to their place of work or recreation and then show the change in angle to a burglary site and are illustrative of the close alignment of offending locations with routine activity paths. One of the Rengert and Wasilchick graphs is shown in Figure 1. All of the offenders’ work locations are plotted along the axis from home to 0 degrees, and the locations of the burglaries are plotted based on distance and angle from the home/0 axis. There is a clear tendency to prey in the areas close to the optimal (least-distance) path from home to work.

In addition to direct qualitative evidence from offender interviews, there is also indirect quantitative evidence that more general property and violent offending are both highly opportunistic. Some of the initial research in relation to situational crime prevention was in response to the charge that location-specific intervention would merely result in displacement. Indeed, if offending was not opportunity-based then individually tailored, local crime reduction practices would see little measurable impact. The evidence is overwhelmingly to the contrary (Barr and Pease 1990; Hesseling 1994;

Figure 1



Note: The work places of a number of offenders are shown as black squares along the left, horizontal axis from Home to 0 degrees. The offense locations of the burglaries committed by these offenders are shown as black crosses. There is a clear tendency to offend along the general direction toward work, with little deviation into areas that are greater than 45 degrees from the line from home to work.
Source: From Rengert and Wasilchick, 2000. Courtesy of Charles C Thomas Publisher, Ltd., Springfield, Illinois.

Weisburd and Green 1995) and often more suggestive of a diffusion of benefits in many cases (Clarke and Weisburd 1994; Green 1995). The success of situational crime prevention, and the related approach of problem-oriented policing (Goldstein 1990; Leigh, Read, and Tilley 1998; Scott 2000), would appear to suggest that opportunity does play a significant role in offending in many cases and that those opportunities are located along the routine activity pathways that offenders travel. If we are to better understand the spatial and temporal constraints that act to limit offender movement, then it is necessary at this juncture to define a notation for space–time interaction.

Time–Space Notation

Before discussing the influence of temporal constraints on criminal behavior in space, it is useful to establish a temporal framework for time geography. The idea of time acting as a constraint on human behavior is not new and from a spatial perspective can be traced at least back to the work of Hägerstrand. Classic time geography is centered on the notion of constraints as limits to human activity, and more specifically capability constraints, coupling constraints and authority constraints (Hägerstrand 1970:12). The first constraints are those imposed by the individual themselves, due to biological constraints such as the need to sleep and eat, the need to return to a home base for rest, and the physical limits of the body in terms of reach and vision. Coupling constraints "define where, when, and for how long, the individual has to join other individuals, tools, and materials in order to produce, consume, and transact" (Hägerstrand 1970:14). Authority constraints are a measure of organizations external to the individual that control access to different places at different times. Although the distinctions between different types of constraints are useful from a theoretical perspective, this article will refer to the general group of constraints as *temporal constraints* in recognition that the key point to each of the constraints is the limit on the temporal behavior of individuals.

Constraints include the need to participate in activities with others (such as work or meetings, which limit participation in activities in other places) and the ability of public and private agencies to limit or restrict access to some people all or some of the time. Examples include gated communities that limit access to some people all of the time, shopping malls that can restrict unwanted people all of the time and everyone during certain times (outside business hours), and sports stadiums that limit access to certain people (ticket holders) during limited time periods (Miller 2005).

Time geography therefore distinguishes between activities that are fixed (such as school or work) and flexible (such as recreational activities), but criminologists may be more familiar with the terminology of obligatory (or nondiscretionary) and discretionary activities (Rengert and Wasilchick 2000:24; Robinson 1999:29).

Although Hägerstrand's (1970) notion of time geography provides a conceptual framework, it has not resulted in a wide body of micro-level temporal crime research. One possible cause for the lack of temporal research into spatial crime patterns at the micro-level may be the frequent lack of temporal certainty in crime recording. Due to the absence of the owner when many property offenses take place, police records are often temporally accurate but wildly imprecise. In many police databases, these date and time ranges are known as either the *from* date and time and the *to* date and time, or the *start* and *end* date and times. Aoristic analysis (Ratcliffe 2000; Ratcliffe 2002) provides one way to derive meaningful spatio-temporal intelligence from these often spatially accurate, temporally vague data. Aoristic analysis is a spatio-temporal smoothing technique that calculates the probability that an event occurred within given temporal parameters, and sums the probabilities for all events that might have occurred in a time period to produce a temporal weight for a given area or set of areas (Ratcliffe 2002). This approach tends to be most useful for high volume crime data where aggregation provides an opportunity to discern general spatio-temporal crime patterns. It is of less value, however, for individual characteristics of single crime events or single offender crime series.

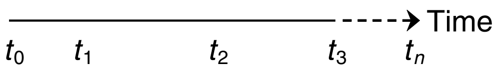
The lack of temporal certainty in the crime offense time recorded in property crime records is usually too limiting to permit constructing an accurate picture of individual offender behavior. Recently, Miller (2005) has developed a theoretical framework for time geography allowing articulation of spatio-temporal behavior in a quantitative manner with analytical definitions that encourage the application of time geography to offender behavior. The following discussion draws heavily on Miller (2005) and employs his notation.

Time is envisaged as a continuous variable that although it can be observed continuously, is more commonly measured at discrete intervals. These become individual "snapshots" at times t_i, such that t_0 precedes t_1 which in turn precedes t_2 and so on until t_n. Each snapshot represents a measurement period where a variable, or the location of an object, is measured. On its own, time can be represented as a one-dimensional line that can only be traveled in one direction, forward. This is shown in Figure 2, which shows time as a single entity with measurements taken at different times (t_0, t_1, . . . t_n).

When the spatial dimension to any human activity is added, it is necessary to represent a physical location, which we do here as x_i. For our purposes, x_i represents a location in space that can be represented by a coordinate system in either two-dimensional (x, y) or three-dimensional (x, y, z) space, though a four dimensional space, with time as the fourth dimension is easily possible (x, y, z, t). Although there is no inherent limitation on the number of multidimensional spaces that can be represented by what is commonly termed a *location*, for convenience and ease this article will refer to x_i as a location that can be represented geographically as an *xy* coordinate pair.

If a person's location is known at a certain time, then his or her space-time location can be represented as being at location x_i at time t_i. If the person then moves on to another location some time later, we can record the person as being at x_j at time t_j. Each space–time location can be thought of as a control point: a place where a known space–time location is recorded.

Figure 2
A Simple One-Dimensional Timeline



Although space–time locations between control points are often unknown, the travel velocity between the two control points x_i and x_j can be shown:

$$v_{ij} = \frac{\|x_j - x_i\|}{t_j - t_i}$$

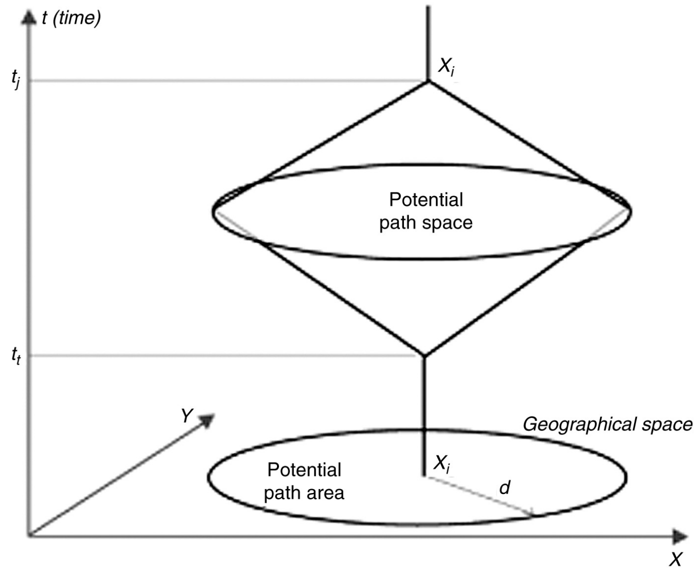
where $\| \;\|$ represents the distance between the two control points.

Consideration of velocity is useful because there is a temporal cost to traversing physical space, and this is the case for all individuals, including offenders. Although the exact route and speed of an offender at any time between t_i and t_j is not known, physical means of transport places an upper limit on the amount of space that can be covered in the available time. For example, offenders with access to cars can travel farther in the same time than offenders on foot.

The physical limits of travel within a certain time can be visualized in the space–time prism. The space–time prism can exist between any pair of temporally adjacent control points if there is a discernable temporal interval between them. In this time interval (t_i, t_j), an individual has an opportunity to engage in activities or to travel to different places, with the temporal constraint of having to be at location x_j at time t_j, as long as the distance between x_i and x_j is small enough (relative to [t_i, t_j]) to allow for some discretionary behavior. Discretionary activity is also possible if the time interval is large enough, or the velocity is fast enough, to permit other activities. In summary, the time interval (t_i, t_j) has to be large with respect to $\|x_i - x_j\| v_{ij}^{-1}$.

Figure 3 shows a space–time prism for an individual who has a time constraint of being at the central location identified as the center of the potential path area (x_i), until time t_i. The potential path area is the whole area that can be accessed by the person at some point in time during the available *time budget* ($t_j - t_i$) assuming they travel at maximum available velocity. The radius of distance *d* denotes the maximum range of the individual during (t_i, t_j) at a point midway between t_i and t_j. The potential path area does not include the

Figure 3
Space–Time Prism Showing the Available Potential Path Area for Discretionary Time with a Single Origin/Destination

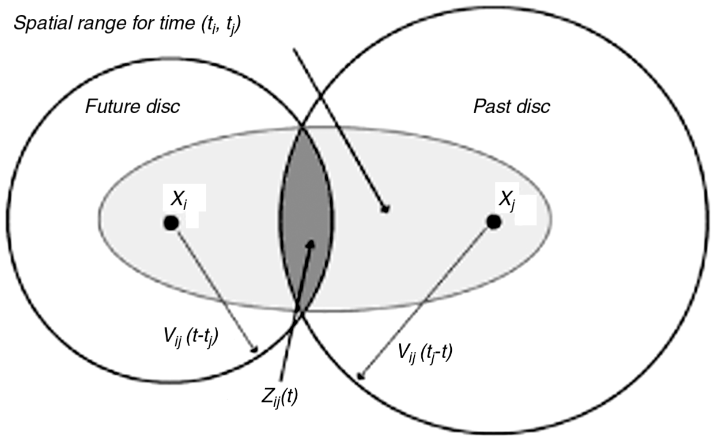


Source: After Wu and Miller (2005).

time necessary to commit a crime, but simply shows the maximum area that it is possible to cover given the constraints of time and transport.

The full range of space–time locations that the person can travel to in the available time is shown by the potential path space, which assumes a maximum velocity constrained by the mode of transport. The potential path space identified by the interior of the prism shows all locations *and* times that an individual can occupy in the time interval from t_i to t_j. Although the potential path area can be thought of (in a flat-world representation, such as a map) as a two-dimensional area that shows the whole potential area that can be accessed by an offender, the potential path space shows a three-dimensional space occupiable at a particular time. As such, the three dimensions are an *x* and *y* coordinate, two dimensions that indicate a location in space, and *t*, a time dimension. The potential path space is therefore time dependent and indicates the potential location of an offender (or victim) at a particular time.

Figure 4
Intersection of Space–Time Discs for a Person Moving from x_i to x_j



Source: After Miller (2005).

As can be seen from Figure 3, immediately after t_i, the space–time prism is quite narrow. This is a recognition that it is not possible to travel far because only a small amount of time has transpired since t_i. Similarly, as the time gets closer to t_j, the prism again shrinks because the individual will need to be close to the point of origin (essentially the trip destination) in order to be at the location by time t_j. If it were possible to measure the potential path area of an individual at every conceivable time between t_i and t_j, then we would be able to see that each space–time potential path area is a disc with a radius d determined by both the amount of time that has passed since t_i and the amount of time remaining before t_j. Figure 3 is a simple example where the origin (x_i) is the same location as the destination, and a more realistic example would be one where the destination is a different site. This would result in the top single strand of Figure 3 being at a different place and skewing the shape of the prism, however, the process remains exactly the same (Figure 4 on p. 22 of Miller, 2005, shows such a skewed prism).

If the origin and destination are different, the potential path area at any time is a fluid intersection of two discs, as shown in Figure 4. In this figure, we assume for convenience that maximum velocity can be achieved in any direction, though it is recognized that the real urban mosaic offers a range of barriers that limit travel speed in different places. If we assume that the image relates to a journey taken by an offender who leaves x_i at time t_i and has to be at x_j at time t_j, then at an intervening time denoted by t (where $t_i < t < t_j$), it is possible to estimate the area that the offender could occupy if maximum velocity is known. This area is described as a disc with a radius of $v_{ij}(t - t_i)$—maximum distance travelable in the time available at best speed. Using Miller's (2005) notation, this area is $f_i(t)$, the set of locations that can be reached from x_i by the elapsed time $t - t_i$. This is shown as:

$$f_i(t) = \left\{ x \left\| x - x_i \right\| \leq (t - t_i) v_{ij} \right\} \quad (1)$$

The set $f_i(t)$ is a closed, convex set referred to as the *future disc* and shows the possible locations available in the future moment t from x_i. In three-dimensional space, the shape is dictated by physical geography such as hills, valleys, and buildings, but the point is most easily illustrated in two-dimensional space. A two-dimensional approach is also the most applicable to crime researchers using a GIS to model offender behavior.

Similarly, if it is known when the offender has to be at x_j, then the temporal constraint imposed by this commitment limits the range of places that the offender can occupy. This range is shown by a disc with a radius of $v_{ij}(t_j - t)$—maximum distance travelable in the time remaining at best speed. This range of locations that can reach x_j in the remaining time budget of $t_j - t$ is $p_j(t)$, also known as the *past disc*, where:

$$p_j(t) = \left\{ x \left\| x_j - x \right\| \leq (t_j - t) v_{ij} \right\} \quad (2)$$

The intersection of these discs (the area of Figure 4 denoted by the darkest shading) shows the spatial range of the offender at time t. Given equations (1) and (2), this disc intersection area is as follows:

$$Z_{ij}(t) = f_i(t) \cap p_j(t) \quad (3)$$

As time progresses, the area of the disc on the left will grow and the disc on the right will shrink. The size of $Z_{ij}(t)$ is dependent on the amount of *reserve time* available to the individual undertaking the journey from x_i to x_j. For example, if the journey time is 30 minutes, and the offender has a temporal constraint (such as starting school or work) that requires them to be at the destination in 30 minutes' time, then the two circles centered respectively on x_i and x_j will not overlap, but will just touch at their circumferences. In other words, if the minimum travel time between x_i and x_j is t^*_{ij}, where:

$$t^*_{ij} = \left\| x_j - x_i \right\| v_{ij} \tag{4}$$

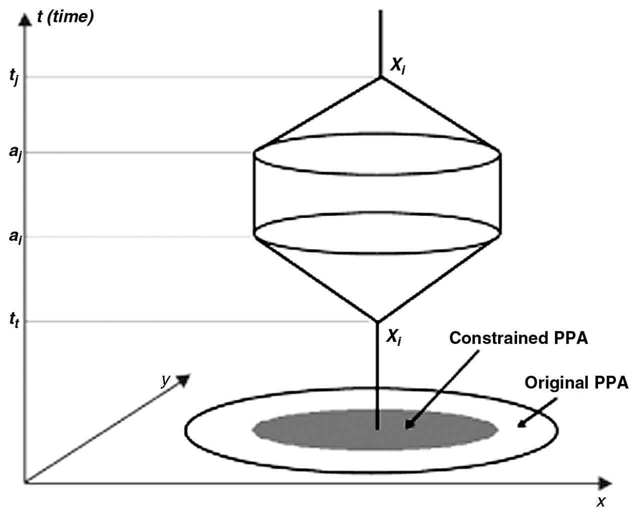
then $Z_{ij}(t)$ will be a single point if $t_j - t_i = t^*_{ij}$. If $t_j - t_i \leq t^*_{ij}$ then it is not possible to reach x_j within the time budget available, and if $t_j - t_i > t^*_{ij}$ then there is reserve time available for other activities, including alternative route selection or offending. The two discs from Figure 4 centered on x_i and x_j are evaluated for one t as some time between t_i and t_j. If it were possible to evaluate every t between the two time references then it could be possible to construct a continuous series of discs and to evaluate $Z_{ij}(t)$ for every moment between t_i and t_j. The continued intersection of these discs from t_i to t_j describes an ellipse that is the aggregate spatial range of the offender given the spatio-temporal constraints of (x_i, t_i) and (x_j, t_j). This ellipse is the spatial range of the offender from time t_i to t_j and is shown in Figure 4 as a light grey ellipse. This general range of locations is described in equation 3. The ellipse is a two-dimensional shape with a foci of x_i, x_j, major axis length of $(t_j - t_i)v_{ij}$ and minor axis of length $\left[((t_j - t_i)v_{ij})^2 - \|x_j - x_i\|^2\right]^{\frac{1}{2}}$. As Miller (2005) notes, this shape collapses to a circle when $x_i = x_j$.

At present, we have not considered offending time. Most property offending takes a certain amount of time and takes place at a stationary point, referred to in time geography as an activity time (a_{ij}). Although a stationary activity, such as offending, is a temporal constraint (with a time budget of the time required to commit the offense), in essence it also acts as a spatial constraint, limiting the full extent of d in Figure 3 by constricting the prism at its widest point. This revision to the potential path area (PPA) is shown in Figure 5 where the constrained area (shaded in gray) denotes the smaller area to conduct the activity due to the amount of time it takes to perform the activity (a_i, a_j). Note that although the journey start and end site is the same location (hypothetically an offender's home or work place) and is therefore shown as x_i for both ends of the journey, it is equally possible that the offender moves to another location after the offense (which would have been shown as x_j at another location). For ease of comprehension, the graphic from Figure 3 is adjusted.

This additional constraint can be reflected in a revised estimation of $Z_{ij}(t)$ if an activity is to be conducted, such that (from Miller 2005):

$$Z_{ij}(t) = f_{ij}(t) \cap p_j(t) \cap g_{ij} \tag{5}$$

Figure 5
The Potential Path Area (PPA) from Figure 3 is Now Constrained by the Need to Conduct an Activity (a) for a Set Period of Time



where g_{ij} is the set of locations that can be reached from x_i and still have time to conduct the activity and reach x_j by t_j, such that:

$$g_{ij} = \left[((t_j - t_i - a_{ij})v_{ij})^2 - \left\| x_j - x_i \right\|^2 \right]^{\frac{1}{2}} \tag{6}$$

The area $Z_{ij}(t)$ is shown as dark gray shading in Figure 4. With this basic notation in place, this article proceeds to place these concepts of space–time geography into a criminological context by examining offender spatial behavior.

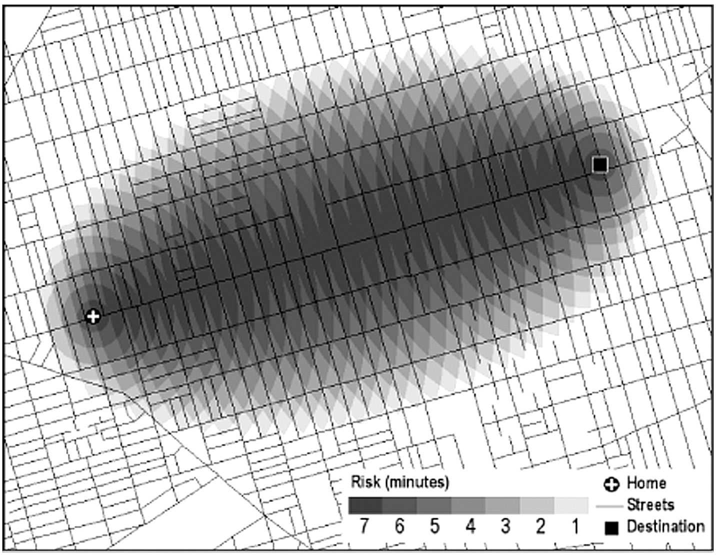
Temporal Constraints and Criminal Behavior

From a criminological perspective, if a substantial proportion of offender criminal behavior is largely driven by response to an opportunity encountered during a non-crime-related journey, then the temporal constraints of nodes will define offender exposure to criminal opportunities across space. In essence, it will be the noncriminal activity that is foremost in defining the spatial arrangement of criminal opportunities for each offender. All of the constraints that apply to any noncriminal activity will transfer to an offending behavior pattern. For example, we can begin by thinking about noncriminal behaviors such as going to an airport to catch a flight or going to school. Most people do not travel to an airport days prior to a flight as there is little value in waiting days before a departure. Most people therefore arrive at an airport from one to three hours before they are due to leave, anticipating the amount of time necessary to travel to the airport, check-in, and reach the departure gate, as well as building in a little extra time to allow for possible delays in either getting to the airport or delays at the airport. We can think of the *time budget* allocated to these instances comprising of both a *journey time*, being the time required to actually get to the airport, and a *reserve time* being the time left over to allow for unexpected problems. The reserve time can easily be swallowed up by an accident on the way to the airport, or a long queue at check-in. The temporal constraint is therefore defined as the time of the flight (t_j) and the location of the airport (x_j) relative to the starting point of the traveler (x_i). These three parameters are used by people to determine what time they should leave the starting point (t_i). Greater reserve time allows for either more time to loiter en route to or at the airport, or the option to take alternative routes. Reserve time not dedicated to travel therefore defines the possibilities to use varying routes away from the predetermined (usually a shortest distance) route or to conduct other activities.

Similarly, consider a youth traveling from home to school. Most young people aim to walk to school to arrive close to starting time. In other words, if a youth has to be at school by 9 a.m., and the shortest journey time is 33 minutes, then the student must leave home by 8:27 a.m. to avoid getting into trouble. If the student leaves home at 8:20 a.m., then there are only seven minutes available in the reserve time budget for route variation or other activities.

To demonstrate this in a two-dimensional format, consider Figure 6. The intersection area $Z_{ij}(t)$ for a 33-minute journey (with 40 available minutes) can be mapped for every minute for a journey from the example youth's home to the destination (school). Using a GIS, it is possible to combine the individual space–time discs (from Figure 4) that individually represent $Z_{ij}(t)$ for each minute (equation 3) and in doing so show the ellipse that represents the spatial range for time (t_i, t_j). If the individual $Z_{ij}(t)$ discs are combined and their degree of overlap totaled, we can calculate the risk time for specific locations on the offender's available routes.

Figure 6
Areas of Potential Crime Risk, $Z_{ij}(t)$, Measured in Minutes, for an Offender Traveling from Home to a Destination, with Seven Minutes Reserve Time, Assuming that Any Offense Takes Little or No Time to Commit



Note: The street pattern is artificial and provided for context.

Figure 6 shows that locations on the immediate path of the offender are at potential risk for the greatest length of time. In other words, the youth can loiter in these areas for the longest amount of time before having to continue the journey to the destination. The *risk time* rapidly reduces for locations that are not located along the most direct path. The spatial range ellipses for different reserve time budgets can be visualized by interpolating from minute to minute. Of course, this example assumes that offending takes little or no time, but an adjustment can be made for this, as follows.

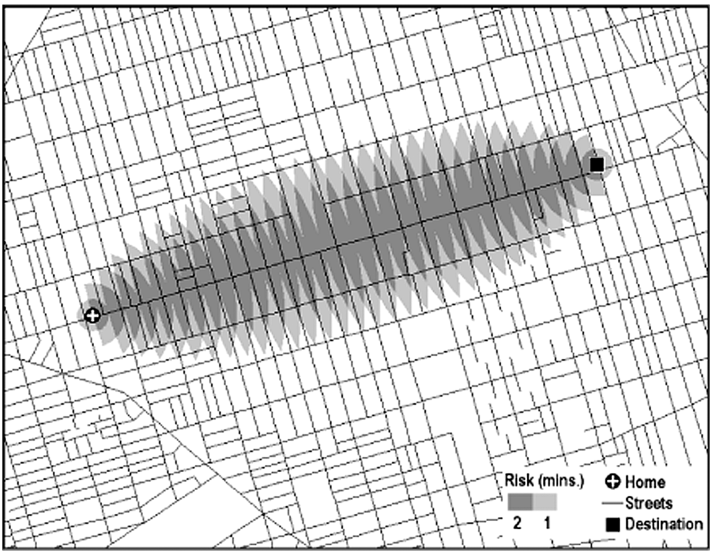
If the youth in this example has a propensity to graffiti, and if our example youth's tag requires five minutes to create, then the amount of reserve time available to select a tag site is only two minutes. The five minutes required to create the tag suggests a stationary activity time (a_{ij}), which as explained above, acts as a spatial constraint, revising the set of locations that can be reached from x_i while still having time to reach x_j by t_j (see equation 6).

For our example youth intent on an act of graffiti, this temporal constraint of actually conducting the activity (a_{ij}) leaves little time to explore much beyond the shortest path to school without running a risk of being late and getting into trouble. The temporal constraint of the school starting time acts as an inhibitor to straying far from the path between home and the school. Greater exploration increases the chance of being late, assuming that being late is something that the youth wishes to avoid and that lateness has some sanction applied by the school. This is shown in Figure 7 where the $Z_{ij}(t)$ discs have been recalculated to include a five minute offense time. In this way, each discs represents the revised spatial range of $Z_{ij}(t)$ from equation 5 (revised from equation 3).

Of course, the problem can be resolved by leaving home earlier, say at 8 a.m.; however, if we concur that crime opportunities often arise as a result of noncrime journeys (as stressed earlier) and if the trip to school originates as a noncrime journey, then the youth would expect to arrive very early for school (by 8:33 a.m.) and have to wait around half an hour for school to start. Unobtrusive observations of 50 randomly selected elementary school children in Lincoln, Nebraska, found that after leaving school, 88 percent of the students walked directly to a residence, and 98 per cent chose a least-distance path from their school to their destination (Hill 1984). Arriving closer to the start time is the norm for school children as it is for adult life and the journey to work. In other words, although more crime opportunities become available if the journey is started earlier, why would an offender bother if they did not originally anticipate that the trip would create crime opportunities? If we accept the evidence produced earlier that many crime events are opportunity-based, then noncrime journeys would appear to dominate the daily routine of offenders, and journeys close to the minimal possible travel time budget would be the norm.

Time therefore acts as a constraint on offender movement, especially in relation to obligatory activities. The constraints placed on the offender directly relate to the target risk. Returning to the example used in this section, as time creeps closer to 9 a.m. (school start time), the spatial location of potential targets for graffiti creeps closer to the school. The immediate vicinity of the youth's home is not available for graffiti at 8:50 a.m. because there does not exist sufficient time to tag a site (five minutes) and then cover the 33-minute journey to school. Property close to school is more at risk as 9 a.m. approaches because the impending commencement of the school day acts as a temporal constraint, forcing children into the vicinity of the school at this

Figure 7
Areas of Potential Crime Risk, Measured in Minutes, for the Youth Offender Traveling from Home to a Destination, with 7 Minutes Reserve Time, Assuming that Any Offense Takes Five Minutes to Complete



time. Of course, the imminent start of school does not just force our example youth into the vicinity of the school, but also a large number of potential graffiti artists. The risk of crime victimization therefore becomes strongly dependent on time when considering the risk to a stationary target (such as a parked car or house) in relation to an individual offender's travel pattern. At the commencement of the trip to school, properties around the offender's home are at risk of graffiti from about 8:20 a.m. to 8:27 a.m. Once the offender has to move toward school and the offender moves through the urban mosaic, the risk to any property near home evaporates (at least in regard to this offender). Property on or near the shortest or usual journey path are at risk for only a few minutes in the morning as the darkest lens shape from Figure 4, representing $Z_{ij}(t)$, passes by. These risks are directly related to the temporal constraint imposed by, in this case, the need to attend school.

This example demonstrates that if a potential offender's temporal constraints are known, then the potential risk to people and property can be mapped both spatially and temporally. Of course, it is also recognized that the model is most effective when the temporal constraint imposed by the target destination is an enforceable one that carries sanctions or a penalty so as to realistically enforce the temporal constraint. This issue will be returned to in the discussion.

The Cost of Deviations from the Shortest Path

When the ellipse that defines the spatial range for (t_i, t_j) is examined (see Figure 4), it becomes clear that the search area that is available for exploration while en route to a node is limited spatially. The temporal constraint imposed by the destination node limits the area of search, and when the time of offense is deducted from the time budget then the shape of the overall ellipse becomes even narrower. The inclusion of the time necessary to commit an offense works to reduce the ellipse, such that the major axis becomes $(t_j - t_i - a_{ij})v_{ij}$ and the minor axis becomes $\left[((t_j - t_i - a_{ij})v_{ij})^2 - \|x_j - x_i\|^2\right]^{\frac{1}{2}}$. The latter equation is of particular interest to environmental criminologists, as it implies that the activity time (in a criminological example, the time to commit an offense) reduces the potential path area perpendicular to the main axis from x_i to x_j. The Brantinghams have hypothesized that a significant reason why offenders do not search for opportunities far from their normal activity path is because the criminal can quickly move into areas in which they are unfamiliar, do not know escape routes, and where they may be uncomfortable (Brantingham and Brantingham 1984:364). Eck discussed this concept in terms of displacement, where on being displaced from normal criminal opportunities by some crime prevention scheme, there is a reluctance for offenders to take advantage of opportunities in unknown areas, a concept he termed *familiarity decay* (Eck 1993).

There is qualitative evidence to support these ideas (Rengert and Wasilchick 2000; Wright and Decker 1994), but if much offending is opportunity motivated and offending opportunities are identified during noncrime journeys, then the temporal constraints imposed by the need to reach the journey's destination at a certain time may also be a significant explanation for the lack of roaming from the direct path from one node to another. It is hypothesized here that the temporal constraints of daily life are the main cause of unfamiliarity with areas beyond the offender's immediate least-distance path.

Once an offender strays into unfamiliar territory, the average speed of travel is likely to slow due to the necessity to negotiate unknown roads. A slower speed means that less territory is covered in the same time, and the area of ground that can provide a criminal opportunity is reduced. Even if a steady speed can be maintained, any journey that deviates from the predominant direction will quickly erode available time for offending. For example, if an offender decides to turn perpendicular to the shortest distance path to a node, then the perpendicular journey eats into the time budget for the journey. If the node is still to be reached by the required time, then the offender will quickly eat into all the available reserve time and will have to resume the journey. Some deviations will still be in the general direction of the destination node, but as long as this is not along the shortest route, the relative decrease in speed toward the destination will incur a time cost that can only be paid in part from the original time budget for the journey.

One Offender Searching from Home

Even when the offender is less opportunity-driven during an innocent trip, deliberate crime risk is highly temporal for property. Consider an offender who has two spare hours to travel from home to seek out a criminal opportunity such as a residential burglary, and then has to return home for some commitment (for example, a youth may have been told by parents to be home by a certain time, or an individual may have a court-imposed curfew). Given a two-hour window of essentially reserve time, which is uncommitted to any obligatory activity, one might be tempted to think that all locations within one hour's walk of the home address are potentially at risk, however this is not the case. There are two significant temporal constraints. The first is the need to return to the domicile within two hours. The second is to factor in the time required to commit an offense. For example, a burglary might require 20 minutes, comprising 10 minutes to wait near the target property to establish if the occupants are home, if they have an alarm and if there is a dog present; five minutes to effect an entry to the premises; and five minutes to search the home and remove the property. Evidence from interviews with burglars suggests that this estimate of 20 minutes lies somewhere in the modal range (Rengert and Wasilchick 2000). Given a 20-minute time span required to commit the offense, a crime site that is one hour from the offender's home would allow no time to commit the offense. Although $x_i = x_j$, a_{ij} is 20 minutes and this reduces the available reserve time such that $t_j - t_i = 100$ minutes.

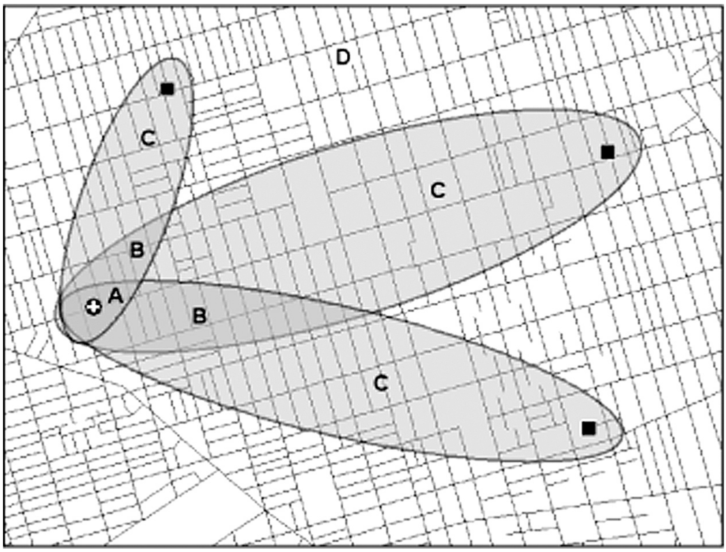
This means that if only one property is to be targeted (offense time 20 minutes) then there is only a time budget of one hour and 40 minutes (100 minutes) available for searching for the target. Given the need to travel to and from the target, only properties within a 50-minute walk of the offender's home are effectively in range.

This picture becomes more complicated when the offender begins to search local streets closer to home first. The likelihood that a burglary will happen at a home 50 minutes from the offender's home address effectively evaporates as soon as a nonlinear search pattern is employed. Unless the offender moves directly in one direction at best speed, the first route variations will eat into time available to achieve the best range within the time remaining before the offender has to be back home. For example, if the offender searches close to home and has not left the vicinity of the home address after 20 minutes, then the only locations that are at risk exist within 40 minutes travel time from the offender home, bearing in mind that it requires 20 minutes to commit the crime and the remaining 80 minutes has to be divided into two to cover the time to get to and from the crime site.

Furthermore, the temporal constraint of having to return home at a certain time will increase the risk closer to home more so than sites closer to the extent of the 40-minute range. As range from home increases, the number of viable properties increases exponentially (Rengert, Piquero, and Jones 1999) yet, if only one site is selected for burglary, the relative risk to each site decreases. The temporal constraint of having to return home within two hours means that houses close to the offender's home will be at risk for most of the two-hour time period, whereas a location 45 minutes away will only be theoretically at risk for a 10-minute block of time around the middle of the two-hour time block. This is because it would take 45 minutes to reach the area, 20 minutes to commit the crime, and 45 minutes to return home. This is a total of 110 minutes, leaving only 10 minutes left of the two hours (120 minutes) to search for a viable target. If the offender has not identified a suitable target after 55 minutes, then there is not enough time to commit the crime and return. In this way, locations further from an offender's home tend to have a reduced time of risk to burglary.

This may help to provide a temporal rationale for the findings that offenses tend to cluster around an offender's home (Rengert and Wasilchick 2000). To this point, this clustering has been explained by both the least effort principle, which states people will not travel further than is necessary to conduct an activity, and crime pattern theory, which hypothesizes that locations close to home will be in an offender's awareness space. The theory of temporal constraints proposed here supports this by suggesting

Figure 8
Three Spatial Ranges Shown for an Offender Residing at the White Cross, and Traveling to the Black Squares



Note: The risk to property is greatest in area A, where all three spatial ranges overlap. The risk along each spatial range is also dependent on the temporal constraints of the destination.

that constraints imposed by the need to be at nodes at certain times limits offending opportunities and concentrates risk close to home. Potential victimization will exist near nodes around the times that the temporal constraint becomes effective, and for many offenders, their home is often a spatio-temporal constraint.

One Offender with Multiple Nodes

Given that most potential offenders will have more than one or two nodes in their daily routines, the spatial location of the nodes has a cumulative impact on the risk of crime on the paths between these nodes. Figure 8 shows the spatial range for an individual located at the white cross, and traveling to three different nodes (shown as black squares).[1] If the individual's behavior is temporally constrained, the available routes to and from these locations will be constrained to the elliptical shapes depicted earlier. This imposes a spatial limit on the areas with which the individual will be familiar and will dictate the likely areas of criminal opportunity for this person. Given that this diagram could be expanded to include the possibility of moving from one node to another without the need to return home again, it becomes clear that areas in the immediate vicinity of nodes will carry the greatest aggregate risk, a risk that remains close to the node but is also highly directional.

As can be seen in Figure 8, the placement of the nodes relates directly to the areas that will be in the offender's awareness space. There is one small area, near the offender's home (labeled A) where all three spatial ranges overlap. This area can be calculated empirically, and Miller (2005) describes an application of Helly's theorem to solve for the intersection of *n* prisms. This area will be the most familiar to the offender because the temporal constraints imposed by the three nodes will dictate likely routes. The property in this area is most exposed to risk as this area falls within the aggregate spatial range of the journeys from home to all three activity nodes. Property at the next level of risk is in the areas marked B, as these are areas where two spatial ranges overlap. Finally, areas marked C are still at risk but less so than the areas A and B. The area marked D is outside of the normal travel routes of the offender and is not considered at significant risk.

These patterns have been observed before. Rengert and Wasilchick (2000) graphed the directional bias of burglary sites in relation to home and work (see Figure 1), and home and recreational sites, of offenders. Their orientation graphs are significantly demonstrative, and they concluded that, "the burglar is strongly influenced by the direction of his workplace in his search for a crime site" (Rengert and Wasilchick 2000:77).

Here the case is made that the cause of the patterns seen by Rengert and Wasilchick (2000), and other researchers, is due to temporal constraints imposed on the offender, and that these temporal constraints are responsible for pattern of offending around paths and nodes. Furthermore, what has not been recognized before is that the risk to property within the spatial range is often short-lived (perhaps only a few moments as the offender passes by) and is temporally dictated by constraints imposed at either the destination or the source of the journey.

The corollary of this is that property located in area A of Figure 8 has to contend with multiple risk as the offender leaves home and returns home again from three different obligatory activities. This is significantly greater (in terms of a lone offender) than the risk to property around a school (in Figure 6 and Figure 7, and the center destination in Figure 8) where the temporal risk is greatest just before opening time and then just after finishing time. Although this section has concentrated on the behavior of an individual offender, it is clear that certain crime generators will impose temporal constraints on victims and offenders alike, creating the conditions to fuel crime at certain times. Home owners close to schools and to rowdy bars experience this, as these locations bring people together all at one time, and often disperse them at a set time. Crime in these areas is likely to be highly temporally specific as a result.

Discussion

This article proposes that the spatio-temporal patterns of opportunity-based crime are highly dependent on the temporal constraints placed on offenders. These temporal constraints, such as work or going to school, influence the travel patterns of noncrime journeys that are central in the identification of opportunities for criminal activity. These travel patterns are affected in both their timing and route. It is hypothesized here that the temporal constraints of daily life are the main cause of unfamiliarity with areas beyond the offender's immediate least-distance path. The corollary of this is that temporal constraints, in conjunction with the locations of offender nodes, are a major determinant in spatio-temporal patterns of property crime.

Furthermore, this temporal constraint theory implies that the risk to property from an offender is often brief and dynamic lasting for only a few minutes or even moments, but doing so at a fairly regular time each day. The opportunity to commit crime will also be affected by the temporal constraints placed on victims, patterns of behavior to which offenders are known to be sensitive (Rengert and Wasilchick 2000), and which have a measurable impact on crime (Cohen and Felson 1979).

Society has long understood this relationship between temporal and spatial patterns and the need for constraints. Prison remains one of the ultimate spatio-temporal constraints that can be imposed on a known offender, and truancy programs and curfews are more limited attempts to restrict the spatio-temporal freedom of potential offenders. Truancy is a recognized risk factor in delinquency, though there is a current lack of rigorous testing of the crime-prevention benefit of truancy programs (Sherman et al. 1998). From a temporal-constraint perspective, truancy prevention may be effective in reducing residential burglary. Given that residential burglary is a predominantly daytime crime, the time of risk is generally during school hours. By requiring a school child to remain at school, this temporal constraint limits their movement during the time of greatest residential burglary activity. For the majority of residential burglars, the ideal opportunity is to break into an unoccupied home. This requirement creates a constraint to wait until all of the household occupants have gone to school or work, and provides an additional constraint to complete the crime before children come home from school or adults return from work. Once school has finished, then returning parents or the presence of school children in the home acts as a victim-induced constraint.

Late-night curfews, on the other hand, are less likely to act as a temporal constraint on residential burglary, however they may act as a temporal constraint on nonresidential burglary and crimes of violence or criminal damage. In some states and countries (e.g., New Zealand) it is common to impose a court-ordered curfew as a bail condition and police are entitled to conduct bail checks to ensure that the offender is at home during the curfew hours. These are often dusk to dawn curfews, however, a greater understanding of the temporal patterns of crime (such as residential burglary) may improve the facility of curfews by timing them to coincide with the times of offending of the individual in question. This would impose a temporal constraint of being at their home address during the highest offending time.

Temporal constraints are most likely to function as an inhibitor to crime-search behavior when the purpose of the journey is primarily noncriminal and there is an obligatory activity awaiting the offender at the destination node; in other words, a journey related to a noncrime compulsory activity. When the temporal constraint at the destination is more fluid, or discretionary, then there exists the possibility of trading more time between the reserve and the journey time budgets. For example, if an offender agrees to meet a friend in a bar for an evening, arrival time is usually flexible within social limits. The temporal constraint of meeting friends is therefore of more limited value as a crime inhibitor. Of more value are activities such as work which acts as a strong temporal constraint forcing an individual to remain at one location for a number of hours in each work day. Even when an employee has a free lunch hour, the constraints of having to return to work within an hour severely hampers the spatial range away from the workplace that can be targeted as well as limiting the available time for offending and criminal opportunity search.

Although 88 percent of the elementary school children reported by Hill (1984) walked directly to a residence after school, it is more likely that older children and teenagers will have the time to vary their route and activities after school. The temporal constraint of getting to school on time is less likely to be replaced by a similarly rigid restraint after school, though after-school programs and sports activities could fulfill this role. It is also recognized that a number of offenders are less likely to have attachments to, and be constrained by, social institutions that provide conventional activities. Their perception of time may also be more fluid than that of the law-abiding, though this could be changing at a societal level. It may be that as traffic congestion increases in our urban centers, and some people are able to work from home more than before, it is becoming increasingly acceptable to be late. If we increasingly accept workers and students arriving late for fixed activities, this changes the patterns of temporal constraint for offenders and victims. A further caveat should be noted here: it is likely that offenders in possession of stolen properly and vulnerable to detection by the police may travel at a faster speed homeward (or toward a criminal fence) than the outward journey.

It should be stressed that property owners should not lower their guard simply because the time that an offender may pass by has concluded. Although there are times when the routine activities of offenders brings them within visual range of a home or parked vehicle, this does not necessarily mean that this is the time that a crime will occur. It should be remembered from the ethnographic research of Wright and Decker (1994) that even when offenders deliberately seek a burglary opportunity, they go to homes that they had identified through noncriminal journeys, or search in familiar areas. The potential for an offense may therefore be greatest when the offender is not temporally constrained but has more free time, perhaps when not going to work for example. Given that the majority of the offenders interviewed by Wright and Decker deliberately sought out criminal opportunities, property should be protected at all times. However, the situational crime prevention key may be to make the house (as an example of a popular criminal target) appear particularly well-protected or occupied at the times when the offender is passing by on the noncrime journey. For example, although residents near schools should always be crime-aware, they should be cognitive that many potential offenders are walking past their home just prior to school starting, and just after school is finishing. As a result, giving the appearance that the home is occupied and secure during these particular times may signal to offenders to seek out other opportunities away from this location when they return to the area for criminal activity later in the day.

Conclusion

It is recognized that this is not a universal theory that explains all offending patterns. Temporal constraints are only as good as their ability to influence potential offender behavior and the emphasis in this article on rigid temporal constraints is a simplifying assumption, one that is deliberately applied to aid comprehension of the concept. Recidivist offenders and career criminals will be less influenced by constraints such as the start of the school bell. Minor infractions, such as starting school or work a few minutes late, will provide for an increase in opportunity to commit crime, however, time-measurement theory is able to include those calculations (where known) and to expand the model of property risk accordingly. Time-measurement theory is also able to include an adjustment for the time required to escape from a crime scene, a feature that is a consideration in some offenses.

The empirical notation from Miller (2005) provides a roadmap to researchers wishing to more formally express the importance of time as a constraint on offender behavior. This greater quantification of what has been a recognized yet fuzzy parameter has implications for both research and policy. Researchers, especially those interested in agent-based modeling, may benefit from a more formal mechanism to express the behavior of offenders and victims across the urban mosaic. Practitioners wishing to better incorporate time into their offender control strategies may find value in this, and hopefully subsequent, work to formalize the spatio-temporal behavior of offenders, and recognize the value of introducing temporal constraints within the community.

The next stage in this work is to re-examine offender spatial behavior patterns with a greater emphasis on the temporal constraints that are part of their lives and which frame their offending opportunities and to construct explanatory models using time measurement theory.

Note

1. For convenience of illustration, the varying risk within the spatial range is not shown, nor is the distinct possibility of moving from one node to another without having to return home again.

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